Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 196.

B. T. GALLOWAY, *Chief of Bureau.*

BREEDING DROUGHT-RESISTANT FORAGE PLANTS FOR THE GREAT PLAINS AREA.

BY

ARTHUR C. DILLMAN,
Assistant Physiologist, Alkali and Drought Resistant Plant-Breeding Investigations.

Issued December 17, 1910.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1910.

BUREAU OF PLANT INDUSTRY.

Chief of Bureau, Beverly T. Galloway.
Assistant Chief of Bureau, G. Harold Powell.
Editor, J. E. Rockwell.
Chief Clerk, James E. Jones.

Alkali and Drought Resistant Plant-Breeding Investigations.

SCIENTIFIC STAFF.

T. H. Kearney, *Physiologist in Charge.*
H. L. Shantz, *Physiologist.*
A. C. Dillman, *Assistant Physiologist.*

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., August 16, 1910.

Sir: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 196 of the series of this Bureau the accompanying manuscript entitled "Breeding Drought-Resistant Forage Plants for the Great Plains Area," by Mr. Arthur C. Dillman, Assistant Physiologist in Alkali and Drought Resistant Plant-Breeding Investigations, Bureau of Plant Industry.

In the Great Plains area, where the rainfall is limited in quantity and is of uncertain distribution, drought-resistant varieties of crop plants are indispensable if farming is to be made a reasonably safe enterprise. Forage plants which can be successfully grown with a limited moisture supply are especially needed in order to build up a well-balanced type of dry-land agriculture. The Department of Agriculture has introduced from foreign countries many varieties that are more drought resistant than those ordinarily grown in the United States, but even these can be further improved and adapted by the use of plant-breeding methods.

The present paper describes the preliminary results of work along this line which was begun by the Bureau of Plant Industry in cooperation with the South Dakota Agricultural Experiment Station in 1906, and is now being carried on by the Bureau on the experiment farms at Bellefourche, S. Dak., and Akron, Colo. The progress that has been made in breeding drought-resistant and otherwise improved strains of alfalfa, amber sorgo, millets, *Bromus inermis*, and other forage plants especially adapted to the area is here reported. In several of these crops new and promising strains have been developed. As soon as a satisfactory test of their comparative drought resistance can be had, the seed of those strains which stand the test most successfully will be increased and distributed. It is believed that this bulletin will be useful, not only because it points out the scope of the work conducted by the Bureau of Plant Industry in this field, but because it describes simple breeding methods which can be applied by the farmers of the area for the improvement of their crop varieties in respect to drought resistance and other qualities.

Respectfully,

G. H. Powell,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

CONTENTS.

Page.
Introduction . . . 7
Objects sought . . . 7
History of the investigations . . . 9
Stations where work is now in progress . . . 10
  Inception of the work . . . 10
  Bellefourche Experiment Farm . . . 10
  Akron Dry-Land Station . . . 12
Alfalfa breeding for drought resistance . . . 12
  Alfalfa breeding at the Bellefourche Experiment Farm . . . 12
    Segregation of strains . . . 12
    Breeding methods used . . . 15
    Uniformity of plants in the progeny rows . . . 16
    Comparative yields of the different strains and progenies . . . 17
    Winterkilling . . . 18
    Future testing of strains . . . 19
  Alfalfa breeding at the Akron Dry-Land Station . . . 19
  Seed production of alfalfa planted in hills . . . 19
Breeding drought-resistant sorgos . . . 20
  Conditions to be met . . . 20
  Sorgo breeding at the Bellefourche Experiment Farm . . . 22
  Sorgo breeding at the Akron Dry-Land Station . . . 23
Breeding drought-resistant millets . . . 24
  Segregation of strains . . . 24
  Results of preliminary work at the Highmore substation . . . 24
  Variety tests at the Bellefourche Experiment Farm . . . 24
  Millet breeding at the Bellefourche Experiment Farm . . . 25
    Breeding methods . . . 25
    Results of the work . . . 25
    Dates of ripening . . . 27
    Uniformity in the progeny rows . . . 27
  Millet breeding at the Akron Dry-Land Station . . . 27
Brome-grass . . . 29
Western wheat-grass . . . 30
Slender wheat-grass . . . 31
Agropyron cristatum . . . 32
Canada peas . . . 32
Summary . . . 33
Conclusion . . . 34
Description of plates . . . 36
Index . . . 37

ILLUSTRATIONS.

Page.

PLATE I. Alfalfa breeding at the Bellefourche Experiment Farm, South Dakota. Fig. 1.—Alfalfa plants in the breeding nursery, showing the first season's growth. Fig. 2.—Selected strains of alfalfa in double-cultivated rows 36

II. Sorgo at the Highmore substation and the Bellefourche Experiment Farm, South Dakota. Fig. 1.—Sorgo, South Dakota No. 341, at the Highmore substation, South Dakota. Fig. 2.—Sorgo progeny row at the Bellefourche Experiment Farm, South Dakota, showing uniformity of plants 36

III. Kursk millet at the Bellefourche Experiment Farm, South Dakota. Fig. 1.—Selection rows. Fig 2.—Progeny rows 36

IV. Agropyron in the grass nursery at the Bellefourche Experiment Farm, South Dakota. Fig. 1.—Rows of Agropyron cristatum. Fig. 2.—Rows of Agropyron tenerum 36

B. P. I.—606.

BREEDING DROUGHT-RESISTANT FORAGE PLANTS FOR THE GREAT PLAINS AREA.

INTRODUCTION.

This paper describes the results so far attained in breeding improved strains of alfalfa, sorgo, millet, smooth brome-grass, and other forage plants adapted to the semiarid conditions of the elevated region lying between the ninety-eighth meridian and the Rocky Mountains. While the work with none of these crop plants has reached completion, it is considered desirable to publish at this time a description of the objects, methods, and preliminary results.

In this plant-breeding work, as in all other investigations bearing upon dry-land agriculture that are carried on by the Bureau of Plant Industry, it is intended to make the results applicable to the whole territory in which similar climatic conditions exist. By conducting the work simultaneously and with the same methods at different stations, comparable results are expected. The working out of this plan should afford a much safer basis for the establishment of broad principles in drought-resistance breeding than could be attained by any strictly local work. Although the actual breeding is at present confined to only two of the dry-land stations, these are representative of a considerable portion of the Great Plains.

At both of these stations the Office of Forage-Crop Investigations is engaged in testing varieties of the forage plants that are believed to be adapted to the climatic conditions of the region. The drought-resistant plant breeding is conducted in cooperation with these variety tests, which not only afford material for the selection of resistant individuals, but give an excellent opportunity for comparing the drought resistance of the new strains developed with that of a large number of existing varieties of the same crops.

OBJECTS SOUGHT.

To make dry-land farming in a semiarid region like the Great Plains a reasonably safe enterprise, drought-resistant crops must be grown. Most of the varieties of crop plants that have heretofore been used in this region have originated in countries of abundant rainfall, like the eastern United States and western Europe. In recent years the Department of Agriculture has introduced a large number of more or less drought-resistant crop plants from foreign countries where the climatic conditions more nearly resemble those of the Great Plains area. Even with these plants, however, preliminary tests show that there is much opportunity for breeding work to improve the quality, increase the yield, and eliminate the less hardy and less drought-resistant individuals.

Cultivated forage plants are greatly needed in the Great Plains area. Until recently this was essentially a stock-raising territory, and although large parts of it are now being divided up into small farms devoted to grains and other crops, it seems altogether likely that stock raising will continue to be one of the chief industries. In the past the chief dependence of the stock grower has been the "range;" in other words, the native growth of prairie grasses. Only scattered attempts have been made to grow cultivated forage plants, but as the region becomes more and more settled there will be an increasing demand for hay and other stock feeds to supplement the wild-grass pasturage. The growing of forage plants is likely to become one of the most important phases of Great Plains agriculture.

The chief limiting factor in the production of crops in this region is the lack of sufficient moisture. One means of meeting this deficiency is the use of tillage methods that will conserve water in the soil, preventing as far as possible loss by evaporation. Another means of attacking the problem is to grow the most drought-resistant varieties that can be obtained. The investigations described in the present bulletin are concerned with developing such varieties by breeding methods.

The principal factors that enter into drought resistance are probably the ability of the plant to develop a root system that will utilize to the utmost a scanty supply of soil moisture and its ability to reduce transpiration, or loss of water, through the leaves and stems when the air is very dry. It is evident that certain species and varieties of crop plants are better equipped in these respects than others, since they wilt less rapidly when the soil moisture is deficient and when hot, dry winds are blowing. Every farmer on the Great Plains knows that under such conditions the sorgos, kafirs, and milos, for example, will remain fresh and green longer than corn; moreover, within the limits of a single crop species there are great differences in drought resistance, some varieties being superior to others. This has been abundantly proved in the course of the variety-testing work of the Office of Grain Investigations and of the state experiment stations, which have shown certain varieties of wheat, oats, barley, etc., to be more drought resistant than others. Finally, every close observer will notice that some individual plants of a variety are markedly more resistant than other plants from the same lot of seed growing beside them. This fact gives the plant breeder an opportunity to produce still more resistant strains of the drought-resistant varieties by the persistent selection of such individual plants.

Other qualities of the plant must not be neglected in breeding forage plants for drought resistance. The quantity and quality of the hay and seed are equally important. The individual plants which are actually most drought resistant may be deficient in yield and quality and will have to be discarded in favor of other individuals of somewhat less drought resistance but in other respects superior. Good seed production is essential not only in species that are grown primarily for the seed, but in those which are grown for hay, since in order to keep the variety drought resistant it is necessary that the seed should be produced in the region to which it is adapted. Fortunately the yield and quality of the seed are generally better in semiarid than in humid regions. This is notably the case with alfalfa, of which most of the commercial seed at present grown in the United States is produced under irrigation and consequently is not the best adapted to dry-land agriculture.

In perennial plants like alfalfa and the principal meadow grasses, hardiness or resistance to winterkilling is another essential characteristic, especially in the northern part of the Great Plains. Early maturity is of great importance in the growth of annual crops. One-half of the annual precipitation in this region occurs from April to July, inclusive. It is therefore desirable to obtain early-maturing strains which will make most of their growth during the period when the soil contains its greatest amount of moisture. In the northern part of the Great Plains the development of locally adapted varieties of sorgos, milos, and other late-maturing crops is hindered by the shortness of the season. In breeding these plants the ability to ripen seed as early as possible is a characteristic that can not be overlooked.

HISTORY OF THE INVESTIGATIONS.

The plant breeding for drought resistance described in this paper is a continuation of the work begun by Prof. W. A. Wheeler in 1904 at the Highmore substation of the South Dakota Agricultural Experiment Station. Professor Wheeler was at that time botanist of the South Dakota station. The writer was associated with him as student assistant in botany and was in close touch, almost from the beginning, with the plant-breeding work carried on under his direction. In the breeding work at Highmore all the principal forage crops of the region were taken up, alfalfa, clover, millet, sorghum, smooth brome-grass (*Bromus inermis*), western wheat-grass (*Agro-*

pyron smithii), and other species. At the outset, variety tests were made with seed obtained from all available sources. More than twenty different varieties of alfalfa, various species of grasses, strains of clover, and varieties of foxtail millet were tested side by side. Numerous individual plant selections were made from the varieties of these crops that proved to be most drought resistant and otherwise valuable.[a]

STATIONS WHERE WORK IS NOW IN PROGRESS.

INCEPTION OF THE WORK.

The Bureau of Plant Industry in 1906 undertook cooperation in the breeding work at Highmore substation, South Dakota, Mr. T. H. Kearney being in charge of the work on the part of the Bureau. In 1907 Professor Wheeler resigned his position as botanist of the South Dakota Agricultural Experiment Station. In May, 1908, cooperation in forage-plant breeding between the Bureau and the South Dakota Agricultural Experiment Station was discontinued and the work of this office was transferred to the experiment farm which is conducted by the Bureau of Plant Industry in cooperation with the project of the United States Reclamation Service, at Bellefourche, S. Dak. Work was begun at Bellefourche with about forty selections of alfalfa, a strain of amber sorgo, and a strain of smooth brome-grass, all of which had been found promising at Highmore. Part of the breeding work at Bellefourche is carried on in cooperation with the variety testing conducted at that station by the Office of Forage-Crop Investigations of the Bureau of Plant Industry.

In 1908 breeding work was also begun at the Akron (Colo.) Dry-Land Station of the Office of Dry-Land Agriculture Investigations, starting with varieties and strains of forage plants that had previously given good results at Highmore and at Bellefourche.

BELLEFOURCHE EXPERIMENT FARM.

The Bellefourche Experiment Farm is conducted by the Office of Western Agricultural Extension,[b] Bureau of Plant Industry, on the Bellefourche project of the United States Reclamation Service in South Dakota. It is located 20 miles east and 4 miles north of the town of Bellefourche. An irrigation canal has been planned to extend through the farm, dividing it into two nearly equal parts. It is on land lying above this projected canal that the drought-resistant breeding is carried on. On part of the land (about 40 acres) the native sod was broken in June, 1907, and this part has been kept under thorough cultivation since that time. Another field of 20 acres was broken in 1908 and a third, of 10 acres, in 1909.

---

[a] The preliminary results of this work were reported by Prof. W. A. Wheeler in Bulletin 101, of the South Dakota Agricultural Experiment Station, published in March, 1907.

[b] During the first year when this breeding work was carried on at Bellefourche the experiment farm was under the direction of the Office of Dry-Land Agriculture Investigations.

The soil conditions here are different from those existing in the greater part of the Great Plains region, the Bellefourche soil being a heavy clay of the Pierre shale formation locally known as ''gumbo.'' This formation underlies nearly the entire State of South Dakota, but it is covered by other formations except in the west-central part of the State. There it constitutes the surface soil of practically the entire area between the Missouri River and the Black Hills. It forms a broad semicircle east of the Black Hills, in South Dakota, and extends northward into Montana and southward into Nebraska. The area covered in South Dakota is probably about 16,000 square miles, being more than one-fifth of the area of the State. This soil takes up water very slowly, so that during very heavy or long-continued rains there is considerable run-off. It has, however, a high capacity for absorbing water. Its moisture equivalent[a] is about 29 per cent. The soil is therefore capable of holding a large quantity of water and retains this moisture well when the surface is so cultivated as to form a protecting mulch. If the surface is not cultivated and is allowed to become dry and baked, the soil cracks badly, owing to the considerable shrinkage in drying. These cracks extend down 4 or 5 feet, allowing the subsoil to dry out. This is often the condition of the fields during the winter and is probably one of the factors which makes winterkilling of alfalfa common in this region. The fine roots of the plants are evidently torn severely in the shrinking of the soil. The large cracks about the plant promote drying of the roots and permit extensive and severe freezing. It is the opinion of the writer that this extreme winter drought in the alfalfa fields has as much to do with the killing of alfalfa plants as the mere fact of low temperature.

The average annual precipitation at the station probably does not exceed 15 inches. At Ashcroft, S. Dak., which is about 65 miles northwest of the Bellefourche Experiment Farm, the average annual precipitation during the seventeen-year period from 1892 to 1909 was 14.2 inches. The average seasonal precipitation, April to August, inclusive, was slightly over 9 inches. At the Bellefourche station records of the seasonal (April to August) rainfall have been kept for only two years. The totals are as follows: 1908, 8.6 inches; 1909,

---

[a] As defined by Briggs and McLane in Bulletin 45, Bureau of Soils, U. S. Department of Agriculture, this term indicates the percentage of moisture to dry weight of soil that remains after a centrifugal force equivalent to 1,000 times gravity has been applied to the saturated soil.

13.3 inches. The greater part of the rainfall in this region occurs during the early growing season, and the latter part of the summer is liable to be exceedingly dry.

Although the soil type at Bellefourche is peculiar to only a part of the region, the similarity of the climatic conditions is such that we may expect that strains of forage crops developed at this station will be adapted to the greater part of western North and South Dakota and eastern Montana.[a]

AKRON DRY-LAND STATION.

The Akron Dry-Land Station is conducted by the Office of Dry-Land Agriculture Investigations of the Bureau of Plant Industry. The farm is located about 4 miles east of Akron, Washington County, in northeastern Colorado. It was selected as a desirable place for breeding drought-resistant forage crops because of its central location in the Great Plains. The climatic conditions are probably more severe here than in the greater part of the central Great Plains, but in general the station is representative of a large part of the area. The altitude of the station is nearly 4,700 feet, being about 1,800 feet higher than the Bellefourche station. The average annual precipitation, as computed from the records at several places in eastern Colorado, is about 17 inches, though the precipitation at Akron for the past few years has slightly exceeded this.

The land at the Akron station, on which the plant-breeding nursery is located, was broken from the native sod in June, 1907, and has been under cultivation ever since. The soil may be classed as a loam, and is generally favorable for the production of crops when sufficient moisture is present. The soil is typical of the "hard lands" of the Great Plains, as distinguished from the "sand lands" of eastern Colorado, western Nebraska, and other sections of this region. The moisture equivalent of the Akron soil is about 17 per cent, which indicates that it is only medium in water-storing capacity.

ALFALFA BREEDING FOR DROUGHT RESISTANCE.

ALFALFA BREEDING AT THE BELLEFOURCHE EXPERIMENT FARM.

SEGREGATION OF STRAINS.

In the alfalfa breeding at Bellefourche, while increased drought resistance has been the principal object in view, it has been necessary also to take into consideration hardiness, seed production, and the yield and quality of the forage. All selections have been made with the idea of combining large forage and seed production in the same individual plant, the forage type, however, receiving first consideration. A thorough test of the yields of all strains developed is made in broadcast plats and in cultivated rows. It should be said that no proper test of drought resistance has been had in the alfalfa-breeding work up to this time. During the time the work was carried on at Highmore, from 1905 to 1907, inclusive, the annual rainfall was above the average for that station. The season of 1908 at Bellefourche was a dry one, but this was the year when the breeding work was begun there and the plants were too young to afford records of yields under dry conditions. But since the first season's growth of an alfalfa plant is a critical period in its life, and since these selections made a good growth at Bellefourche in the comparatively dry year, 1908, it would seem that they must be at least fairly drought resistant.

---

[a] In transferring the breeding work from Highmore to Bellefourche, the crops were placed under different conditions of soil and a slightly different climate. The soil at the Highmore substation is a glacially deposited clay loam, containing some sand. The altitude is a little less than 1,700 feet, as compared with 2,900 feet at the Bellefourche station, and the precipitation is about 17 or 18 inches annually. Highmore may be considered as located near the eastern edge of the Great Plains, while Bellefourche is representative of the more arid portion of the northern Great Plains.

During the season of 1909 the precipitation was again above the average, so that no test of drought resistance was secured that year. It will therefore be necessary to retain all of the progeny rows and plats until a proper test of drought resistance is secured.

The alfalfa stocks used in the breeding work at Bellefourche consisted of selections from six strains which were grown at the Highmore (S. Dak.) substation. Two of these strains, South Dakota No. 162 and No. 164, are recommended by Prof. W. A. Wheeler in Bulletin 101 of the South Dakota Agricultural Experiment Station as the best of the stocks tested at Highmore. The twenty stocks tested there included several hardy stocks imported by the Department of Agriculture previous to the year 1905. The two best varieties, which are described on a later page of this bulletin, proved to be perfectly hardy and of good forage and seed producing ability. Four other stocks tested at Highmore, which proved fairly hardy, are also represented in the breeding plats at Bellefourche. In the following discussion each strain is designated by a letter, the selections made from each strain being numbered in consecutive order; as A–1, E–12, etc.

Strain A.—This is South Dakota No. 65. The seed was screened from a lot of durum wheat imported from Tashkend, Turkestan, in 1902, by the United States Department of Agriculture. It was planted in 1902 on a small plat, about 12 by 50 feet, at Brookings, S. Dak. This plat went through four seasons there (from the spring of 1902 to the fall of 1906), and did not suffer any from winterkilling.

"Seed from this plat [harvested in 1904] was planted at the Highmore substation, in 1905, in a selection row. A few of the plants in this row died during the winter of 1905–6, showing that it is not perfectly hardy under severe test."[a] The plants now growing at Bellefourche represent the fourth generation of seed. They are somewhat coarse, with stems inclined to be stout and not greatly branched. The results obtained this season indicate that this strain is fair in seed production.

---

[a] Wheeler, W. A. Bulletin 101, South Dakota Agricultural Experiment Station, p. 135.

Strain B.—This is South Dakota No. 66. "The seed was obtained by Prof. N. E. Hansen, from Merke (lat. 43° N., long. 73° E.), northern Turkestan in 1898 for the United States Department of Agriculture. It was distributed by the department as S. P. I.[a] No. 1169. It was sown in a small plat at Brookings in 1899 and has not winterkilled to date. The seed from this plat was sown at Highmore in 1905 in selection rows. The results seem to show it to be about equal to No. 65 in quality, hardiness, and seed production."[b] The plants of this variety are large, coarse, woody in texture, and poor in amount of branching. It has proved the poorest in seed yield of any of the varieties tested at Bellefourche.

Strain C.—This is South Dakota No. 67. "The seed was obtained from the Minnesota experiment station as Minnesota No. 3 in 1902."[b] Minnesota No. 3 was derived from seed purchased by the Minnesota experiment station from a commercial seed firm under the name of "Grimm" alfalfa, but has shown itself to be different from that variety in hardiness and other qualities. It is similar in type of plant to strain E described below, but is somewhat inferior in both forage and seed yield.

Strain D.—This is South Dakota No. 150, purchased from a seed firm as Turkestan alfalfa. It is similar in type of plant to the other Turkestan strains, which are inclined to be woody, spreading, and lacking in leafiness and branching.

Strain E.—This is South Dakota No. 162. This strain originated from the Grimm alfalfa which has been grown near Excelsior, Minn., for more than fifty years.[c] In all the tests at Brookings, Highmore, and Bellefourche it has proved superior to all other stocks tested in seed production, hardiness, and forage type of plant. The selections grown at Bellefourche are inclined to be very leafy, much branched, with short internodes and fine stems. This gives the maximum amount of palatable forage. The selections have proved to be uniformly good in seed production, which is a valuable characteristic of these selections, since the seed yield is one of the important features of the crop in the Great Plains region.

---

[a] An abbreviation for the Office of Foreign Seed and Plant Introduction of the United States Department of Agriculture.

[b] Wheeler, W. A., loc. cit.

[c] Brand, C. J. The Acclimatization of an Alfalfa Variety in Minnesota. Science, vol. 28, 1908, p. 891. Westgate, J. M. Bulletin 169, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909. Science, vol. 30, 1909, p. 184.

Strain F.—This is South Dakota No. 164, which is thought to be S. P. I. No. 991, a Turkestan stock. This strain is less coarse and is better in quality of forage than most of the Turkestan varieties. In amount of seed produced it stands second to strain E, as noted in Table I.

A part of the selections with which the breeding work was begun at Bellefourche were made in 1907 by Mr. John Cole, now of the Office of Dry-Land Agriculture Investigations of the United States Department of Agriculture, but at that time connected with the South Dakota Agricultural Experiment Station and in charge of the Highmore substation. These are selections A 1 and 2, B 1, C 1–4, D 1 and 2, E 1–7, and F 1–3. Selections E 9–16 and F 4–12 were made at the Highmore substation in 1906 by Prof. W. A. Wheeler. Selections E 17–31 and many other selections not described in this bulletin were made by the writer.

BREEDING METHODS USED.

In the alfalfa-breeding nursery (Pl. I, fig. 1) plants are grown singly in hills 21 inches apart, the rows being 42 inches apart. This allows 75 plants to a row in the regular plats of the station, which are 8 rods long. The seed from a single plant is generally planted in one row of hills, but when sufficient seed was available, two rows of hills have been planted to a single selection, and when the quantity of seed available was small, less than a full row has been planted to a selection. Where less than a row was planted there were 25 or 50 hills instead of 75, as in a full row. The hills are planted at definite distances apart so that the rows of plants are in line in both directions. (See Pl. I, fig. 1.) Each row is given a progeny number and each plant within the row an individual number corresponding to the number of the hill in which the plant grows. If a plant is missing in the row the order of numbering is not changed, each plant in the row being permanently designated by the position it actually occupies. This system makes a convenient and certain means of designating each plant and obviates the use of stakes except at the head of the row.

At the period when the first blossoms appear the plants in the nursery are studied carefully and complete notes are taken as to the type of plant, the amount of branching, leafiness, and the color of the flowers. The forage type of plant is best judged at this time, for it is at this stage in the development of the plant that it should be cut for forage. After these notes are taken all the inferior plants, together with such as are divergent from the type of the row, are cut and removed from the nursery. This is done in order that the pollen from these inferior plants will not be carried to and fertilize the flowers of the superior plants. It may be explained further that all plants at the ends of the rows are discarded. This is done in order to secure comparable results of yields per plant from each progeny row, as the end plants, because of their favored position, make a larger growth. The purpose is to secure accurate comparative yields of all the progeny rows.

Later in the season, when the seed is ripe, the superior individuals are selected as mother plants to furnish seed for planting the following season and thus continue the work of selection.[a]

After the superior plants have been selected the bulk of the plants in the row are harvested, dried in shocks, weighed, and thrashed. Since a record is kept of the number of plants harvested, an accurate estimate of the producing power per plant of each row is easily made. The yields of the progenies grown at Bellefourche during the season of 1909, which are in the fourth generation of selection, are presented in Table I.

UNIFORMITY OF PLANTS IN THE PROGENY ROWS.

Breeding work with a plant like alfalfa has the special advantage that one is able to compare living plants belonging to different generations of selection. Alfalfa being perennial, the mother plants can be retained in their original places in the breeding nursery for comparison with their progeny. Thus, the degree in which the progeny has inherited the desirable characters of the mother plant can be checked by direct comparison. In general, there has been great uniformity in the rows although they are the progeny of plants that were selected without any precaution to insure close pollination. As shown in Table I, in 29 out of 36 progeny rows harvested separately, in which the plants "off type" were discarded, over 80 per cent of the plants in each row were harvested as uniform in type. Some prominent types may be noted, as E–2, in which the plants were very erect, rather slender, and only moderately branched, and had dark-purple flowers. This is a rather distinct, easily recognizable form and it will be noted that 84 per cent of the plants in this row conformed to the type. B–1 is another distinct type; the plants are tall, coarse, slightly branched, and woody, with very light purple flowers fading to white. Of the plants in this row 92 per cent were typical. In some progeny rows the variation in type of plant has been great, but in general the uniformity is close enough to show that this method of simple selection without isolation can give valuable results in breeding alfalfa.

---

[a] Heretofore the plants have not been inclosed with screens to insure self-pollination; but it is the plan in future work to inclose a number of plants and pollinate them by hand and thus get a comparison of the uniformity of progeny of screened plants and those which are exposed in the normal way to the chance of cross-pollination by insects. These screens will be placed over the plants at the beginning of the blossoming period. Hitherto the only distinction made with superior plants has been to harvest them separately at the time the seed matured.

COMPARATIVE YIELDS[a] OF THE DIFFERENT STRAINS AND PROGENIES.

TABLE I.—*Uniformity and seed yield of plants of alfalfa grown in progeny rows at Bellefourche, S. Dak., in 1909.*

Strain.	Progeny No.	Proportion of typical plants in progeny rows.	Average dry weight per plant.	Average seed yield per plant.	Seed yield per 100 grams of dry plant.
		Per cent.	*Grams.*	*Grams.*	*Grams.*
A	1	91	138	21	15.2
	2	88	129	16	12.4
B	1	92	153	12	7.8
C	1	82	150	14	9.3
	2	81	150	21	14.0
	3	79	135	16	11.9
	4	85	132	20	15.1
D	1	89	138	13	9.4
	2	85	123	17	13.8
E	1	79	171	27	15.8
	2	84	171	18	10.5
	3	72	....	23	....
	4	88	189	33	17.5
	5	80	144	23	16.0
	6	82	192	32	16.7
	7	80	150	25	16.7
	9	91	150	22	14.7
	10	90	138	22	16.0
	12	100	150	21	14.0
	13	95	138	19	13.8
	15	74	180	27	15.0
	16	83	....	28	....
	17	85	138	20	14.5
	18	66	165	28	17.0
	19	84	180	33	18.3
F	1	85	144	18	12.5
	2	76	150	20	13.3
	3	81	150	19	12.7
	5	87	135	14	10.4
	6	87	132	15	11.4
	7	91	134	22	16.4
	8	83	192	28	14.6
	9	57	144	17	11.8
	10	85	....	21	....
	11	82	144	20	13.9
	12	91	180	30	16.7

The results given in Table I were obtained from a large number of plants. Where the progeny occupied two rows of the breeding nursery the number of plants harvested in the bulk lot exceeded 100. Where the progeny occupied one row the number of plants usually exceeded 50, but where less than a row was planted the report shows the yield of only 20 to 50 plants. Yields estimated on more than 50 plants should represent fairly the producing power of the progeny under this system of planting. Column 3 of Table I shows the percentage of plants of uniform type in the progeny row, leaving out of consideration the inferior plants which were discarded early in the season.

The dry weight of the plants and the seed yield have been reduced to an average per plant so as to afford a comparison of the producing power of the progeny. Column 6 of the table gives the seed yield per 100 grams weight of plant, showing the relation between the seed yield and forage production in each progeny row. It will be seen that a large seed yield is usually associated with a large forage yield, as is shown by a comparison of columns 4 and 5. This result throws some light upon the question whether or not heavy seed production and heavy forage production are opposed, or whether they can be combined in the same individual; the results seem to indicate that these two characteristics can be combined. This purpose has, in fact, been constantly kept in mind in the selection of the mother plants.

---

[a] The yields obtained in the breeding nursery, where each plant has much more space than in ordinary field culture, do not necessarily indicate that under field conditions the different strains will be found to occupy the same relation to each other in comparative yielding power.

Table II is inserted to show the comparative yields of the strains represented in the breeding work. It will be seen that strain E exceeds all others in both seed yield and forage production, as shown by the yield per plant, and that large seed yield and heavy forage production can be combined in the same strain.

TABLE II.—*Proportion of plants winterkilled and average yield of each strain represented in the alfalfa-breeding nursery at Bellefourche, S. Dak., in 1909.*

Strain.	Variety from which derived.	Winter-killing, 1908–9.	Total number of plants harvested.	Average dry weight per plant.	Average seed yield per plant.
		Per cent.		*Grams.*	*Grams.*
A	Turkestan		182	147	18
B	Do	2	132	153	12
C	Grimm		281	141	18
D	Commercial Turkestan		121	132	14
E	Grimm	4	601	162	24
F	Turkestan	1	354	150	21

WINTERKILLING.

The winterkilling of the varieties in the breeding nursery during the winter of 1908–9 was practically negligible, while the broadcast plats and cultivated rows of the same varieties did not show any killing at all. The nursery method of planting, where each plant stands alone and unprotected, is the most severe test of hardiness. At the Ashcroft (S. Dak.) Weather Bureau station, where conditions are probably most nearly representative of the Bellefourche Experiment Farm, a temperature of −30° F. was recorded in January, 1909.

It should be said that the varieties of alfalfa represented in the breeding plats at the Bellefourche Experiment Farm have been subjected to severe winterkilling tests for several generations. They represent selections, some of three and some of four generations of individual plants grown in the breeding nursery at Highmore under conditions which eliminated the less hardy individuals. The minimum temperatures recorded during the time the work was carried on at the Highmore substation are as follows: 1904, −27° F.; 1905, −36° F.; 1906, −31° F.; 1907, −27° F. There was some winterkilling during each of these winters, especially in the breeding nursery, where the test is most severe. The winter of 1905–6 was especially severe; among 20 stocks tested at Highmore, 8 winterkilled greatly and were discarded. Some winterkilling was noted in all the varieties except South Dakota No. 162, which is strain E of the above table

FUTURE TESTING OF STRAINS.

The bulk seed from each of the best progeny rows was planted in 1910 under two conditions, in cultivated rows (Pl. I, fig. 2) and in broadcast plats. If conditions favor a test, the comparative drought resistance of the different strains, progenies, and individual plants will be carefully noted. At the beginning of the season a record of their hardiness and earliness of development was made. Later in the season comparisons of yields will be made from the broadcast plats as to forage production and from the cultivated rows as to seed production. If the progenies which have proved superior thus far continue to show superiority in these characters, combined with hardiness and drought resistance, seed from them will be increased and distributed as soon as possible.

ALFALFA BREEDING AT THE AKRON DRY-LAND STATION.

The plan followed at Bellefourche in the alfalfa-breeding work has been followed at the Akron Dry-Land Station. There is not likely to be so severe a test of hardiness or resistance to winterkilling at Akron as farther north in the Great Plains. The test of drought resistance, however, is likely to be quite as thorough.

The strains of alfalfa are the same as those used at the Bellefourche Experiment Farm. The plan has been to divide the seed of the selections made at Bellefourche and from other sources and plant part of the seed at Bellefourche and part at Akron. In this way a comparison of the effect of somewhat different climatic and soil conditions can be made and the possibility of obtaining an adequate test of drought resistance is increased. As the breeding nursery was established in 1909, no results have yet been obtained except notes on the season's growth and the autumn stand of each progeny row.

SEED PRODUCTION OF ALFALFA PLANTED IN HILLS.

Maximum seed production in alfalfa can no doubt be attained by growing plants in such a manner as to allow cultivation of the soil rather than by planting in broadcast plats. The method of planting in single or double cultivated rows has been recommended[a] and is unquestionably an improvement over the broadcast method for seed production. The results as to seed production in the breeding nursery at Bellefourche suggest that the method of planting in hills is still more favorable to seed production and may be used to good advantage where it is desired to increase rapidly the seed of some valuable strain. It was observed that the yield of seed in the breeding plats at the Highmore substation was often fairly good when the broadcast plats yielded little or no seed. In 1907 a commercial seed firm in South Dakota, with which the writer was then associated, obtained a yield at the rate of 200 pounds of seed per acre in the alfalfa-breeding nursery of half an acre. The plants were grown singly 18 inches apart, in rows 36 inches apart. In the breeding nursery at Bellefourche in 1909 the yield of seed was much greater than from alfalfa seeded in broadcast plats or in double-cultivated rows. These yields are presented in Table III.

---

[a] Brand, C. J., and Westgate, J. M. Circular 24, Bureau of Plant Industry, U. S. Dept. of Agriculture.

TABLE III.—*Seed yield of alfalfa planted in hills compared with broadcast or row planting.*

Plat No.	Method of planting and variety.	Seed yield obtained on $\frac{1}{10}$-acre plat.	Yield per acre.	Yield estimated on perfect stand.
		Pounds.	*Pounds.*	*Pounds.*
67	Breeding nursery, 475 plants, strains D and F, in hills	20	200	348
69	Breeding nursery, 500 plants, strain E, in hills	26	260	430
61	Broadcast plat, strain of Grimm alfalfa	12	120	....
62	Double-cultivated rows, strain of Grimm alfalfa	8½	85	....

In plat 67, 325 plants, and in plat 69, 350 plants, were discarded or missing. The missing plants had been destroyed chiefly by pocket gophers. In estimating yields the living plants nearest these were discarded as having had an unduly favorable opportunity. For this reason column 4 is added, estimating the yield per acre of a perfect stand in the breeding nursery, which would be 825 plants on the $\frac{1}{10}$-acre plat.

The method of planting in hills or very thinly in single rows can be recommended only where rapid increase of seed is desired, as when some especially valuable selection is grown. With the present interest in alfalfa breeding and the great need for drought-resistant and hardy strains, the price of seed of superior strains is likely to be high. Under such conditions the above method of seed increase may be used to advantage.

BREEDING DROUGHT-RESISTANT SORGOS.

CONDITIONS TO BE MET.

Sorgo is an important forage crop in the central and southern Great Plains, but its use in the northern part of the region has been limited because the season is too short to allow the crop to mature seed. Sorgo is not likely to be planted extensively in regions where seed can not be matured. To purchase seed every year often makes the crop unprofitable. Further than this, the greatest food value of the crop can not be secured unless it reaches the point of flowering at the time of harvesting. The purpose in the breeding work described here has been to obtain a drought-resistant and productive strain which will mature early. Such a strain would extend the sorgo-growing area north of its present limits.

The breeding work with sorgo at Highmore and Bellefourche has been done with a saccharine sorghum of the Minnesota Amber type, South Dakota No. 341. This strain has slender stalks and rather long, narrow leaves. The plants stool quite freely, having from two to six suckers per plant. The seed panicles become open and spreading as the seed ripens. The seeds are reddish yellow in color when separated from the glumes. The glumes, however, are black and either smooth or slightly hairy. In thrashing, many of the seeds separate from the glumes. The stock of this variety was found at the Highmore substation in 1903 under the name of "Montana." This is all that is known about its history. It was grown at Highmore in 1906 in comparison with two other amber types and proved to be two weeks earlier than the varieties with which it was compared. The earliness of the type has made it valuable as a stock from which to work. Two valuable selections (Pl. II, fig. 1) were made in the course of the breeding work at Highmore, and seed of these has been increased and is now on the market.

The two selections referred to were very marked in point of earliness and in uniformity of the progeny. It is probable that the early flowering of the mother plant in each of these selections prevented cross-pollination from any of the surrounding plants, which were ten days or more later in flowering. This insured self-fertilization and the resulting uniformity of progeny.

Yields of sorgo, South Dakota No. 341, at the Highmore substation for three seasons, 1906 to 1908, inclusive, and at the Bellefourche station for 1908 and 1909, were furnished by the Office of Dry-Land Agriculture Investigations. These yields are from each of two $\frac{1}{10}$-acre plats used in the rotation experiments of that office and are as follows:

TABLE IV.—*Yield per acre of air-dry fodder at Highmore and Bellefourche, S. Dak.*

Place and year.	Yield of rotation No. 33.	Yield of rotation No. 34.	Average yield.
Highmore:	*Pounds.*	*Pounds.*	*Pounds.*
1906	11,140	10,810	10,975
1907 [a]	4,940	5,760	5,350
1908	8,150	7,250	7,700
Bellefourche: [b]			
1908	2,330	4,200	3,265
1909	4,280	7,560	5,920
Average per acre of all plats			6,642

[a] The low yields in 1907 at Highmore were due to a poor stand of plants in both plats.

[b] The lower yields in rotation No. 33 than in No. 34 at Bellefourche for both years, 1908 and 1909, are due to the poorer type of soil where the plats of rotation No. 33 were located. The soil there is very poor in spots, being liable to puddling and to extreme baking when dry.

The average yield of 6,642 pounds of feed per acre at these two stations is sufficient to warrant the growing of this strain where forage of this kind is desired.

SORGO BREEDING AT THE BELLEFOURCHE EXPERIMENT FARM.

In 1908 the writer obtained some of the bulk seed of the South Dakota No. 341 stock from the Highmore substation and planted a field with it at Bellefourche for the purpose of making selections. In September, 1908, 18 individual selections were made in this field. These were selected for earliness, amount of stooling, and uniformity of the main stalk and suckers in height and ripening. The selections ranged in date of ripening from September 10 to September 20, in height from 4½ to 5½ feet, in yield of seed from 50 to 100 grams, and in number of suckers from 3 to 5 per plant. The characters which make the most desirable type of forage sorgo are slender stems, uniformity in the size of the suckers on each plant, and large total leaf surface, and these points governed the selection.

The seed of each of these selected plants was planted in a single row, 8 rods long, in 1909. In date of ripening the progeny rows were very similar to the mother plants, ranging from September 10 to September 18. In height the progenies exceeded the respective mother plants by about 6 inches, the plants ranging from 5 to 6 feet high. This was probably due to the more favorable season in 1909. Each individual row was quite uniform as to height and type. (Pl. II, fig. 2.)

In order to show what characters apart from drought resistance are regarded as most important in a sorgo for the northern Great Plains and to give some idea of the amount of diversity still remaining in this selected stock, short descriptions are given of the types that predominated in the 1909 progenies of the five most promising selections. It is possible that strains derived from more than one of these selections may ultimately be found valuable for this region. Thus, near the northern limit for sorgo culture the earliest maturing strain, even if somewhat inferior in other respects, may prove to be the most useful, while farther south a later developing strain which produces a better quality of forage may be preferred.

Selection No. 2.—Plants in this row stooled freely; the stalks were small and fine and there were many small suckers which would make forage of good quality. The progeny was good in seed production and uniform in early ripening. This was one of the best rows.

Selection No. 6.—This was a good row, but was slightly later than that of selection No. 2 in ripening seed. It was very uniform in height and type of plant. The plants were very leafy and had numerous suckers that were slender and fine.

Selection No. 9.—This was about the best row in the breeding plat; the plants stooled freely, the stalks were small, and the plants uniform in height and type. It was early and uniform in ripening seed.

Selection No. 10.—This row was very similar to that of selection No. 9 except that the plants were later in maturing and the stalks were slightly thicker. (See Pl. II, fig. 2.)

Selection No. 12.—This was a fairly good row; the stalks were small and the plants stooled freely and were early in ripening. A peculiarity of this row was that a large percentage of the outer glumes of the seed were free from hairs.

Bulk seed was saved from each of the above selections. This seed was harvested September 16, when nearly all the plants in the breeding nursery were mature. Seed from each row was harvested separately by cutting the mature panicles from all the plants that showed the type characteristic of the row. No comparisons of yields of either seed or forage were made, as the differences in stand in the different rows would have made the comparison of little value. The bulk seed from each row was planted in field plats in 1910 for comparison of their drought resistance, yield, uniformity, earliness, and other characteristics. The writer believes that sorgo can be made a valuable crop in the northern sections of the Great Plains if this early-maturing type is planted. Since no strain that will ripen seed is at present generally grown in this region, it would seem desirable to increase seed of these superior selections as rapidly as possible for distribution to farmers.

SORGO BREEDING AT THE AKRON DRY-LAND STATION.

Seed of each of the selections made at Bellefourche in 1908 was planted in single rows 8 rods long at the Akron Dry-Land Station in 1909. Each of the plants selected in 1908 bore two or more panicles of mature seed. The seed from one of these panicles was planted at Bellefourche and the seed from the other at Akron. The progeny was very similar in type of plant and general characteristics to that grown at the two stations, but it is evident that extreme earliness in ripening is not of first importance at the Akron station. The progeny of selection No. 13 was considered the best row there, while at Bellefourche it was decidedly too late in maturing and the stalks had a tendency to be coarse and pithy. This row, No. 13, was harvested for seed, and the seed was planted for comparison with other varieties in 1910.

It is probable that later maturing varieties (for example, Orange and Red Amber) may be grown to good advantage at Akron, and in future drought-resistance breeding work at that locality such varieties will be considered.

BREEDING DROUGHT-RESISTANT MILLETS.

SEGREGATION OF STRAINS.

Several varieties of foxtail millets (*Chaetochloa italica*) are grown rather extensively in the northern Great Plains. This crop is especially valuable there because it requires only a few weeks to complete its development; for this reason it is often used as a "catch crop" to replace other crops which have been frozen or otherwise destroyed in early summer.

Most of the varieties now on the market are mixtures of more or less distinct types and offer an excellent opportunity to the plant breeder to segregate these types and develop pure strains. This has been the purpose of the work here described, special attention being given to the segregation of strains characterized by drought resistance, early maturity, and maximum forage yield.

RESULTS OF PRELIMINARY WORK AT THE HIGHMORE SUBSTATION.

Mention is made in Bulletin 101 of the South Dakota Agricultural Experiment Station of the breeding work with foxtail millets carried on in cooperation with the Bureau of Plant Industry at the Highmore substation. The breeding work was conducted with five varieties of millet—Kursk, Common, Siberian, Hungarian, and German. Several uniform and productive strains were developed at Highmore and were grown for comparison of yields, but the results have not been published in detail. Seed of one pure strain of Kursk millet developed at Highmore has been increased by a commercial seed firm and is now offered for sale. The Office of Forage-Crop Investigations of the Bureau of Plant Industry secured some of this seed in 1907, and it was distributed under S. P. I. No. 22420.

VARIETY TESTS AT THE BELLEFOURCHE EXPERIMENT FARM.

In 1908 breeding work was begun at the Bellefourche Experiment Farm with five varieties of foxtail millet (*Chaetochloa italica*). In cooperation with the Office of Forage-Crop Investigations a preliminary test was made in 1908 of these varieties in $\frac{1}{20}$-acre plats and in 1909 in $\frac{1}{10}$-acre plats. The results were as follows:

TABLE V.—*Yield per acre of five varieties of foxtail millet at Bellefourche, S. Dak., in 1908 and 1909.*

Variety.	Yield of hay from plat.	Estimated yield of hay per acre.
Plats of one-twentieth acre, 1908:	*Pounds.*	*Pounds.*
S. P. I. No. 22420, Kursk	144	2,880
S. P. I. No. 22423, Common	150	3,000
S. P. I. No. 22340, German	116	2,320
S. P. I. No. 22424, Siberian	150	3,000
S. P. I. No. 22426, Hungarian	130	2,260
Plats of one-tenth acre, 1909:		
S. P. I. No. 25220, Kursk	154	1,540
S. P. I. No. 24841, Common	206	2,060
S. P. I. No. 24842, German	68	680
S. P. I. No. 24843, Siberian	194	1,940
Average yield for the two years of the three best millet varieties:		
Common		2,530
Siberian		2,470
Kursk		2,210

About thirty other species and varieties were tested in single rows in 1908, but none of these proved to be of any special value for this region except S. P. I. No. 20694. Seed of this number was obtained by Professor Hansen, at Khokand, Russian Turkestan, in 1906, when acting as agricultural explorer for the Department of Agriculture. A quantity of the seed was planted in a selection row at Bellefourche in 1908. Two plants in this row matured seed and were saved. Since the plants were identical, so far as could be seen, the seed from the two was mixed and planted in a progeny row in 1909. The selection is of good forage type, but the panicle is open and the seed shatters readily.

MILLET BREEDING AT THE BELLEFOURCHE EXPERIMENT FARM.

BREEDING METHODS.

The methods used in the millet-breeding nursery were much the same as in the alfalfa nursery. In 1908 the seed of each of the varieties, Kursk, Common, German, Hungarian, and Siberian, was planted in hills 8 inches apart, in rows 42 inches apart (Pl. III, fig. 1). The seedlings were thinned to single plants in a hill. Selections of the superior individual plants were made and the seed planted in single rows 8 rods long, in 1909 (Pl. III, fig. 2).

RESULTS OF THE WORK.

The table following gives the record of yields and other data concerning the individual plant selections made in 1908 the progeny of which gave the largest yield in 1909:

TABLE VI.—*Yield of millet selections of 1908 and of their progenies grown at Bellefourche, S. Dak., in 1909.*

Variety and selection.	Number of selections in 1908 and of progeny rows in 1909.	Individual selections of 1908.			Progeny grown in 1909.[a]		
		Total dry weight of plant.	Weight of seed.	Proportion of seed to 100 parts of straw.	Total dry weight of plants.	Weight of seed.	Proportion of seed to 100 parts of straw.
		Grams.	*Grams.*	*Per cent.*	*Pounds.*	*Pounds.*	*Per cent.*
Kursk, No. 22420:[b]							
1		100	29	40	28	9½	51
2		125	43	52	29½	9½	48
4		85	16	23	29	9	45
5		130	27	26	30	8½	41
8		120	19	19	28	8½	43
10		130	29	29	27	8¾	48
11		150	22	17	27	8	42
Common, No. 22423:[b]							
1		112	42	60	21	7¾	58
4		95	33	53	18¾	7¼	62
7		100	38	61	19	8	73
8		65	28	76	22½	8½	60
Siberian, No. 22424:[b]							
1		120	25	26	22½	7	45
5		95	8	9	23	6¾	41
9		140	16	13	21½	5	30
10		95	13	16	23	5½	31
Hungarian, No. 22426:[b]							
1		170	15	10	30½	3	11
3		170	13	8	28	4½	19
7		127	19	17	26½	5¾	28
8		120	12	11	25	4½	22
S. P. I., No. 20694:							
1		55	5	10	26	5½	27
2		90	7	8			

AVERAGE YIELDS OF ALL THE SELECTIONS AND PROGENIES.[c]

Variety and selection.	Number of selections in 1908 and of progeny rows in 1909.	Total dry weight of plant.	Weight of seed.	Proportion of seed to 100 parts of straw.	Total dry weight of plants.	Weight of seed.	Proportion of seed to 100 parts of straw.
Kursk, No. 22420	15	108	23	27	27	8⅗	47
Common, No. 22423	8	86	31	56	18	7⅗	63
Siberian, No. 22424	10	122	16	15	21	5⅗	36
Hungarian, No. 22426	8	130	13	11	25	4⅘	24

[a] The yields of the different progenies are strictly comparable because the rows were of uniform length and the stands were all perfect.

[b] Only those selections from each variety are here included of which the progenies in 1909 gave yields of seed and of total dry matter above the average for the progenies of all the selections made in 1908 of that particular variety.

[c] Including selections the progenies of which yielded low in 1909 and were hence excluded from the preceding showing.

Some interesting results are shown in the millet-breeding work as recorded in the above table. It will be noted in the record of averages that the Kursk is the highest yielding variety in the progeny rows grown in 1909, both in total weight of plant and weight of seed. Kursk is considerably ahead of any other variety in yield of seed though the Common variety exceeds it in proportion of seed to straw.

It will also be noted that the yields of seed and straw of the progenies, in general, correspond rather closely with those of the respective mother plants. This is especially marked in the Kursk and Common varieties. For example, in the Kursk variety, seven selections are separately listed in which the progeny of each yielded above the average of all rows. As shown in Table VI, the selected mother plants all yielded above the average in total weight of plant, except No. 1 and No. 4. Selections 6, 7, 9, 12, 14, and 15 (not separately shown in the table) yielded below the average of both mother plants and progeny.

DATES OF RIPENING.

The average dates of ripening and the average number of days from date of planting to maturity for the selected varieties for the two years were about as follows:

TABLE VII.—*Date of ripening and length of growing period of several selected varieties of millet at Bellefourche, S. Dak.*

Variety.	Date of ripening.	Maturing period. (days)
Common	August 24	96
Kursk	August 28	100
Hungarian	September 7	110
Siberian and No. 20694	September 10	113

It will be seen that the Common and Kursk varieties are earlier by ten days or more than the Hungarian and Siberian. Earliness in ripening is an important factor in all dry-land crops, especially millet, which is often used as a catch crop to replace a previously destroyed crop.

UNIFORMITY IN THE PROGENY ROWS.

It was noted in the breeding plats that the progeny rows from the different selections of Kursk resembled one another much more closely than the progeny rows from any other variety. This may be accounted for by the fact that the bulk seed from which these Kursk selections were made was itself the product of two selections made at Highmore only three or four generations back. There seems also to be great uniformity among the plants in each progeny row.

The selected plants have been remarkably true to seed from the beginning, indicating that millet is probably a self-pollinated plant. This belief is based on the general uniformity of the plants in the progeny rows as observed by the writer in all his breeding work with this crop.

MILLET BREEDING AT THE AKRON DRY-LAND STATION.

Seed of several selections of millet made at the Bellefourche Experiment Farm in 1908 was used for beginning the breeding work at the Akron Dry-Land Station in 1909. These selections were the same as those planted at Bellefourche, sufficient seed being borne by each plant for use at both stations.

TABLE VIII.—*Yield of millet selections of 1908 and of their progenies grown at Akron, Colo., in 1909.*

Variety and selection.	Individual plant selections made at Bellefourche in 1908.			Progeny grown at Akron in 1909.				
	Total dry weight of plant.	Weight of seed.	Proportion of seed to 100 parts of straw.	Yields from actual stands.			Stand in row.	Total dry weight calculated to a full stand.[a]
				Total dry weight of plants.	Weight of seed.	Proportion of seed to 100 parts of straw.		
Kursk, No. 22420:	*Grams.*	*Grams.*	*Per cent.*	*Pounds.*	*Pounds.*	*Per cent.*	*Per cent.*	*Pounds.*
1	100	29	40	18¾	7¼	63	80	23.2
2	125	43	52	39	18	86	95	41.0
3	150	25	20	33½	14¾	79	100	33.5
5	130	27	26	42	17	68	100	42.0
10	130	29	29	33¾	14¼	73	100	33.7
13	145	30	26	39½	17½	80	100	39.5
15	100	29	42	28½	12	73	90	31.6
Average	126	30	34	33	14½	75	....	34.9
Common, No. 22423:								
1	112	42	60	22½	10½	87	80	28.0
2	82	40	95	13¾	4¼	45	75	18.3
3	75	33	79	19½	6¼	47	70	28.0
4	95	33	53	27¼	13½	98	95	29.0
7	100	38	61	19¼	9	88	95	20.3
8	65	28	76	24¼	12	98	95	25.6
Average	88	36	71	21	9	77	....	24.8
Siberian, No. 22424:								
1	120	25	26	15½	6¼	68	80	19.4
4	175	25	17	37	15½	72	90	41.0
Average	147½	25	21½	26	10.9	70	....	30.2

---

[a] This calculation is doubtless too favorable to the rows in which the stand was incomplete, since the plants growing near the gaps unquestionably yielded more heavily than would the average plant in a row in which the stand is complete.

The yields of millets in the progeny rows in 1909 were considerably heavier at Akron than at Bellefourche. This fact is not only apparent by comparison of the average yields of all the progenies of each variety at Bellefourche (Table VI) and at Akron (Table VIII), but generally holds good in the case of progenies of those individual selections of which the seed was divided and planted partly at Bellefourche and partly at Akron. The heavier yields at Akron were doubtless largely due to the more favorable season at that locality in 1909. The rainfall there was well distributed throughout the growing season, while at Bellefourche there was less than 3 inches of rain during July and August, which is the critical period in the growth of millet. It was noted that the yield of seed in many of the rows at Akron was remarkably high. The average seed yield of the Kursk progeny rows was 14½ pounds per row, which is equivalent to a yield of 25 bushels per acre. The largest yield, from Kursk selection No. 2, of 18 pounds to the row, is at the rate of 32 bushels per acre.

As shown by the averages for the progenies of each variety, the Kursk is first in total weight of plant and weight of seed. The superior yield of Kursk millet when grown in cultivated rows is a marked character of the variety. This is no doubt partly due to its strong stooling habit and vigorous growth. It has been noted by the writer that in seeding millets broadcast a much heavier stand is secured in the Kursk variety than in others when the same amount of seed is used per unit area. This makes it desirable to seed somewhat less of this per acre than of other varieties, especially under dry-land conditions.

In 1910 the seed of the best progeny rows grown in 1909 were planted in $\frac{1}{10}$-acre plats in comparison with standard varieties. These tests will be continued until the forage value of the different selections as compared with one another and with other varieties under conditions of severe drought can be ascertained.

BROME-GRASS.

Smooth or Hungarian brome-grass (*Bromus inermis*) is one of the most drought-resistant grasses grown in the northern Great Plains. It is well adapted to cultivation on account of its abundant seed production and vigorous habit of growth, and it has come into general favor in the Central Northwest since its introduction into the United States.[a] Several stocks of seed were tested at the Highmore substation previous to and during the time cooperation was carried on between the Bureau of Plant Industry and the South Dakota Agricultural Experiment Station. One of these stocks, listed as South Dakota No. 26, appeared to be decidedly superior to the others in forage production. This strain is rather distinct in type of plant and has light-colored outer glumes or scales around the seeds which give the mature panicle an exceptionally light-colored appearance. The plants are strong and vigorous and remain productive for several years; that is, the strain does not "run out" quickly. Bulk seed of this strain was planted broadcast and in double-cultivated rows at the Bellefourche Experiment Farm in 1909. A breeding nursery occupying two $\frac{1}{10}$-acre plats was also planted. The seed was planted in hills 42 inches apart each way and the hills were thinned to individual plants in early summer. An excellent stand was secured in all the plats. There is great diversity in the manner of growth of the individual plants in the breeding nursery. Many of them are erect and close growing, while others are inclined to spread greatly by rootstocks. There is also great diversity as to amount of leafiness and amount of stooling. Altogether there is great opportunity for selection of superior types. In addition to the work in the breeding nursery tests are being made of several individual selections of *Bromus inermis* furnished by the Office of Forage-Crop Investigations. These are planted in progeny rows.

---

[a] For a chemical analysis of brome-grass, see Table IX.

WESTERN WHEAT-GRASS.

Western wheat-grass, botanically known as *Agropyron smithii* (*A. occidentale*), is native over a large part of the northern Great Plains and is valued highly as a pasture and hay grass. It is especially common on the "gumbo" soils in western South Dakota. Along the river and creek bottoms, where subject to annual overflow, it forms a dense, vigorous growth and is the most valuable native hay grass of the region. In such places it forms a pure growth unmixed with other grasses. On the dry ranges it forms a considerable part of the native forage and is remarkably drought resistant. The growth on the ranges, however, is scattered and thin. In depressed areas where drainage is poor or which receive the drainage from higher areas the wheat-grass occurs to the exclusion of other native grasses. This is doubtless due partly to its great alkali resistance and partly to its ability to endure rather long periods of flooding. The alkali content of the soil in these areas ranges as high as 0.4 to 0.6 of 1 per cent.

Wheat-grass hay is locally in great demand in South Dakota. It is especially valuable for feeding to livery and other horses doing hard work. For this purpose it sells for $4 to $5 more per ton than alfalfa and mixed hay at Bellefourche, Deadwood, and other places in the Black Hills.

Chemical analyses indicate that it is especially rich in crude protein and ether extracts. The following analyses of some common native and cultivated forage plants of South Dakota are here given for purposes of comparison:

TABLE IX.—*Chemical analyses of some common native and cultivated forage plants of South Dakota.*

Name of forage plant.	Name of analyst.	Ash.	Ether extract.	Crude fiber.	Crude protein.	Nitrogen-free extract.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Western wheat-grass (*Agropyron occidentale*).	Shepard [a]	8.52	2.91	34.90	9.80	43.88
	Knight and Kepner.[b]	5.03	3.07	36.70	9.23	45.97
Slender wheat-grass (*Agropyron tenerum*).	Shepard [a]	5.74	2.77	32.44	8.90	50.15
Smooth brome-grass (*Bromus inermis*).	do. [a]	8.08	2.06	41.27	10.79	37.80
	Knight and Kepner.[b]	6.21	2.71	29.50	9.47	52.11
Buffalo-grass (*Bulbilis dactyloides*)	Shepard [a]	11.19	2.46	28.74	5.60	52.02
	Knight and Kepner.[b]	11.60	2.42	26.81	8.34	50.83
Blue grama (*Bouteloua oligostachya*)	Shepard [a]	8.69	2.18	31.40	9.11	48.62
Timothy (*Phleum pratense*)	do. [a]	7.39	3.58	34.39	8.84	45.80

[a] Shepard, J. H. Bulletin 40, South Dakota Agricultural Experiment Station, 1894.
[b] Knight, H. G., and Kepner, F. E. Bulletin 76, Wyoming Agricultural Experiment Station, 1908.

It will be noted that in the percentage of fats (ether extracts) western wheat-grass is very high, being excelled only by timothy. It is also high in amount of crude protein, but is excelled in this by

Bromus inermis. It is therefore very rich in two of the most important food constituents, and this accounts for its great feeding value as demonstrated by the practical feeder. One other character which may be mentioned is the comparatively concentrated form of the cured hay; that is, the weight per unit volume is great as compared with most hay grasses.

Breeding work was begun with western wheat-grass at the Highmore substation by Prof. W. A. Wheeler in 1905. These breeding plats were visited several times by the writer, the last visit having been made in August, 1908. At this time there appeared to be considerable uniformity in many of the progeny rows from the first selections. South Dakota No. 34–89 was uniformly more spreading than the rows at each side of it: No. 34–105 was also noticeably spreading in habit of growth, while No. 34–81 was close growing, showing a slight approach to bunch-grass habit.

Breeding work was begun at the Bellefourche Experiment Farm in 1908 with bulk seed harvested from natural meadows near the farm. It is desired to secure a drought-resistant and productive strain, suitable for establishing permanent grass meadows on unirrigated land. It is very important to improve the seed production and percentage germination of the seed and the early growth habits of the plant. The germination of the seed is poor and slow and the early growth is not vigorous. It is therefore difficult to obtain a good stand of the grass. Both spring and autumn seeding are being tested to determine which method will produce the better stand. The results so far are not conclusive.

A breeding nursery has been established with single plants in hills 42 inches apart each way. These were grown from seed planted in the field in 1909.

SLENDER WHEAT-GRASS.

Slender wheat-grass, botanically known as *Agropyron tenerum*, appeared to be valuable as a cultivated hay grass in variety tests by the South Dakota substation at Highmore, and by the Office of Forage-Crop Investigations at Bellefourche. The seed germinates freely and the first season's growth is good, so that there is not the difficulty in securing a stand that is experienced with western wheat-grass; but this species is apparently not so drought resistant as brome-grass and western wheat-grass.

Seed collected from plants growing native in western South Dakota was planted in the grass nursery at Bellefourche in 1908 (Pl. IV, fig. 2). In 1909 individual plants were selected from this nursery and these will form the basis of the breeding work with this grass.

Considerable variation among the individual plants was noted in height, amount of stooling, and leafiness. The most desirable types were those which have the leaves extending well up along the culms, thus producing a very leafy plant. There was much variation in this regard. In 1910 the seed of these selections was planted in rows so that a close comparison could be made of their progeny. A few individual plant selections of slender wheat-grass were furnished by the Office of Forage-Crop Investigations, and these were planted in progeny rows in 1909.

AGROPYRON CRISTATUM.

The grass botanically known as *Agropyron cristatum,* recently introduced from Siberia by the United States Department of Agriculture, gives evidence of being a very hardy grass. In cooperation with the Office of Forage-Crop Investigations, seed of six different lots, S. P. I. Nos. 19536 to 19541, inclusive, was planted in the grass nursery at Bellefourche in 1908 (Pl. IV, fig. 1), and larger areas were planted again in 1909. It was observed that this species starts growth very early in the spring, and is not injured by severe frosts. In habit of growth it is like slender wheat-grass, being a "bunch-grass" without creeping rootstocks, but in the character of its rather harsh foliage it somewhat resembles western wheat-grass. Further tests will be made of seed from several sources, and if the species proves to be valuable as a hay grass, selections of superior strains will be made.

CANADA PEAS.

The Office of Forage-Crop Investigations tested a large number of varieties of Canada peas, grass peas (*Lathyrus sativus*), and several varieties of vetches at the Bellefourche Experiment Farm in 1908 and 1909. The yields of most of these have not been satisfactory in the two years during which tests have been made. The low yields have probably been due to the newness of the soil at the farm, as the plats were on land broken only one year previous to cropping. Two or three varieties of Canada peas, however, are very promising, and breeding work has been begun with these.

In dry-land farming the need of an annual leguminous crop for use as green manure in short rotations is apparent, and Canada peas promise to be the most valuable crop for this purpose in the northern Great Plains region. The breeding work will be directed to obtaining a more drought-resistant variety than is now grown in the region, combining also fair seed production with a good forage type of plant.

SUMMARY.

The chief limiting factor in the production of crops in the Great Plains area is lack of sufficient moisture. Two ways of increasing crop production in that region are: First, the use of tillage methods which will conserve the moisture in the soil as far as possible for the use of crops; and second, growing drought-resistant varieties.

The object of the plant-breeding work described in this bulletin is to develop strains of some of the common forage crops that are more drought resistant and productive than strains now grown in the region.

Drought-resistant forage-breeding work is now carried on at two farms conducted by the Department of Agriculture in the Great Plains area, at Bellefourche, S. Dak., and at Akron, Colo. These farms are fairly representative of a large part of the northern and central Great Plains.

In breeding alfalfa for this region, while drought resistance is the principal object in view, such characters as resistance to winter-killing, superior forage yield, and good seed production can not be neglected.

The results of the breeding work with alfalfa indicate that superior forage production and superior seed production are not antagonistic, but may be combined in one plant or strain.

Maximum seed production in alfalfa can be obtained by growing plants in hills, allowing thorough cultivation of the soil. This method can be recommended only where seed is the chief object of the crop.

Breeding sorgo at Bellefourche has been undertaken for the purpose of developing a drought-resistant and early-maturing strain of good forage quality. The existence of such a strain would extend the use of the crop considerably north of its present area.

Most millet varieties now on the market are mixtures of more or less distinct types. In the breeding work conducted by this office, several promising types have been segregated and have shown a high degree of uniformity. They will be tested further for drought resistance, early maturity, and forage yield.

Numerous species of grasses have been tested for drought resistance in the course of the breeding work at Highmore, and by the Office of Forage-Crop Investigations at Bellefourche and other stations in the Great Plains area. Breeding work is in progress with species that have proved drought resistant and otherwise valuable, including smooth brome-grass, western wheat-grass, and slender wheat-grass.

CONCLUSION.

It is intended to test thoroughly the improved strains which have been developed in the course of this work in order to determine their relative drought resistance in comparison with varieties now grown in the region. The most promising strains of alfalfa will also be thoroughly tested in respect to their hardiness. As soon as definite results from these tests of drought resistance and hardiness are obtained, seed of such strains as may prove resistant will be increased and distributed.

PLATES.

DESCRIPTION OF PLATES.

Plate I. Alfalfa breeding at the Bellefourche Experiment Farm, South Dakota. Fig. 1.—Alfalfa plants in the breeding nursery, showing the first season's growth. The photograph was taken July 29, 1909, three months after planting. The rows are from individual plant selections of the second generation, South Dakota No. 167. Fig. 2.—Selected strains of alfalfa in double-cultivated rows (rows 7 inches apart alternating with cultivated space 32 inches wide).

Plate II. Sorgo at the Highmore substation and the Bellefourche Experiment Farm, South Dakota. Fig. 1.—Sorgo, South Dakota No. 341, at the Highmore substation, South Dakota. The selected strain at the left is ten days earlier than the bulk seed of the same variety at the right. Fig. 2.—Sorgo progeny row No. 10, showing uniform type of plants. Grown at the Bellefourche Experiment Farm, South Dakota, in 1909, from seed of a single plant selected in 1908.

Plate III. Kursk millet at the Bellefourche Experiment Farm, South Dakota. Fig. 1.—Selection rows of Kursk millet at the Bellefourche Experiment Farm, South Dakota. The individual plants are grown in hills 8 inches apart. Fig. 2.—Progeny rows of Kursk millet grown at the Bellefourche Experiment Farm, South Dakota, in 1909. These are the progenies of plants selected in the rows shown in figure 1.

Plate IV. Agropyron in the grass nursery at the Bellefourche Experiment Farm, South Dakota. Fig. 1.—Rows of *Agropyron cristatum* in the grass nursery at the Bellefourche Experiment Farm, South Dakota. In 1909 this grass was ten days earlier in starting spring growth than any other species in the nursery. Fig. 2.—Rows of *Agropyron tenerum* in the grass nursery at the Bellefourche Experiment Farm, South Dakota. This is a valuable type of hay grass and breeding work is being carried on in the hope of segregating a more drought-resistant strain.

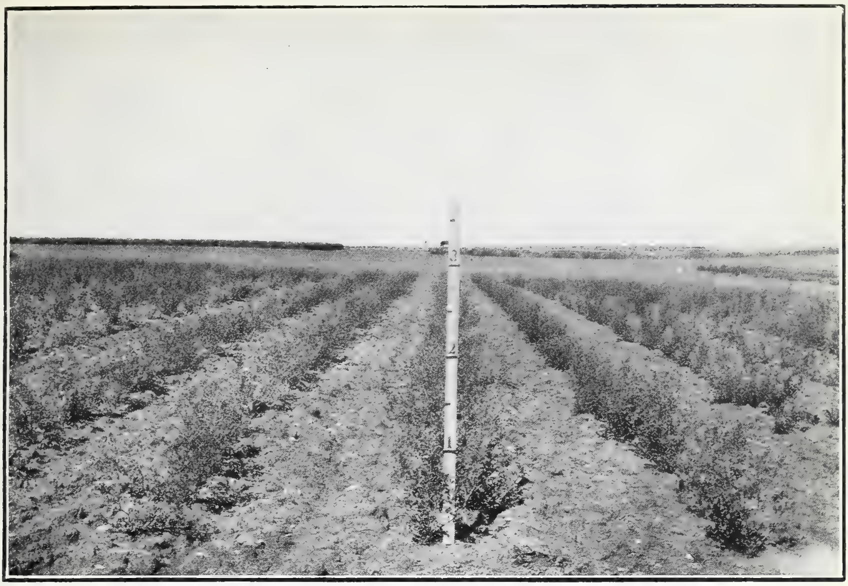

FIG. 1.—ALFALFA PLANTS IN THE BREEDING NURSERY, SHOWING THE FIRST SEASON'S GROWTH.

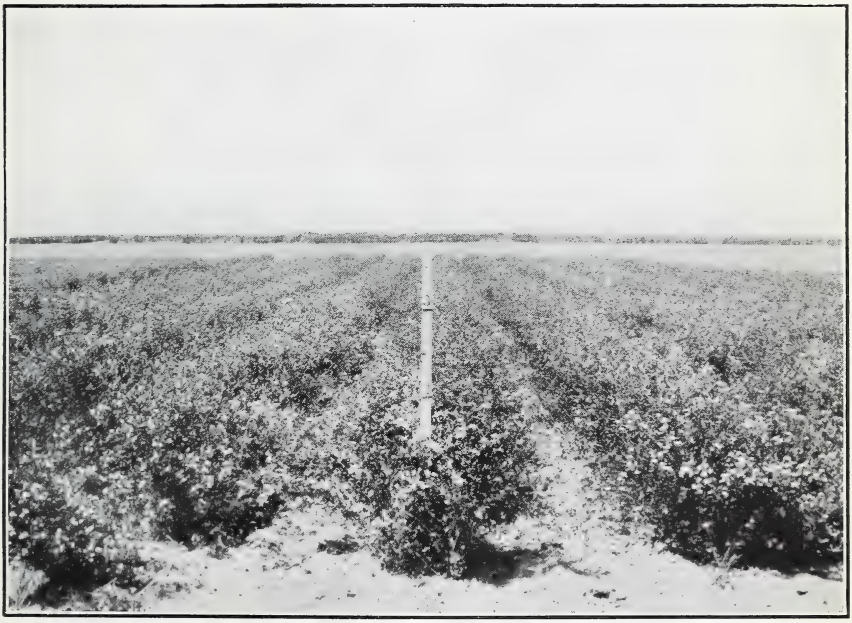

FIG. 2.—SELECTED STRAINS OF ALFALFA IN DOUBLE-CULTIVATED ROWS.

ALFALFA BREEDING AT THE BELLEFOURCHE EXPERIMENT FARM, SOUTH DAKOTA.

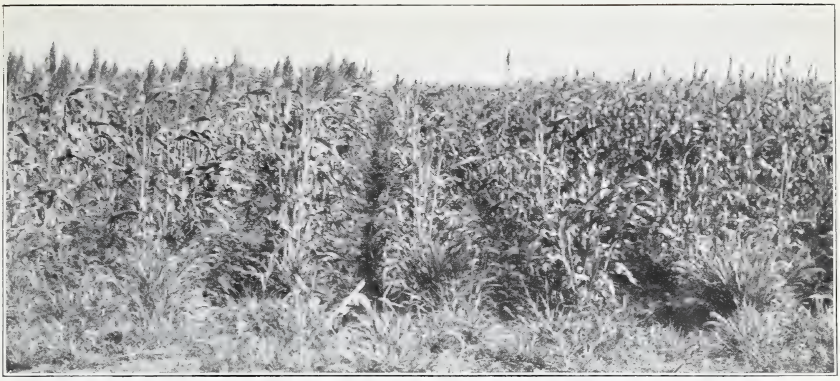

FIG. 1.—SORGO, SOUTH DAKOTA NO. 341, AT THE HIGHMORE SUBSTATION, SOUTH DAKOTA.

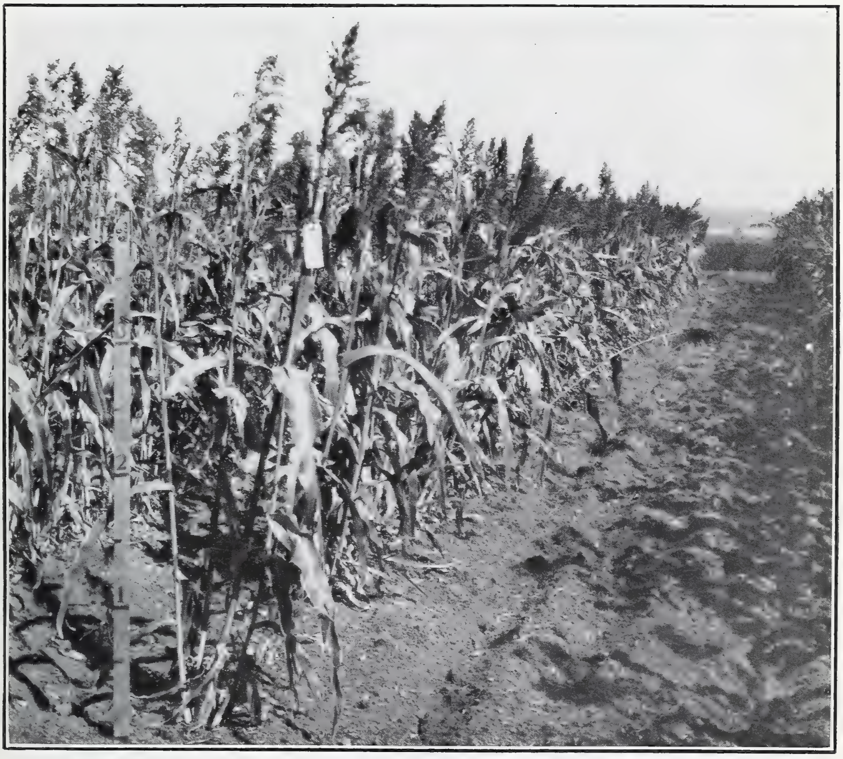

FIG. 2.—SORGO PROGENY ROW AT THE BELLEFOURCHE EXPERIMENT FARM, SOUTH DAKOTA, SHOWING UNIFORMITY OF PLANTS.

SORGO AT THE HIGHMORE SUBSTATION AND THE BELLEFOURCHE EXPERIMENT FARM, SOUTH DAKOTA.

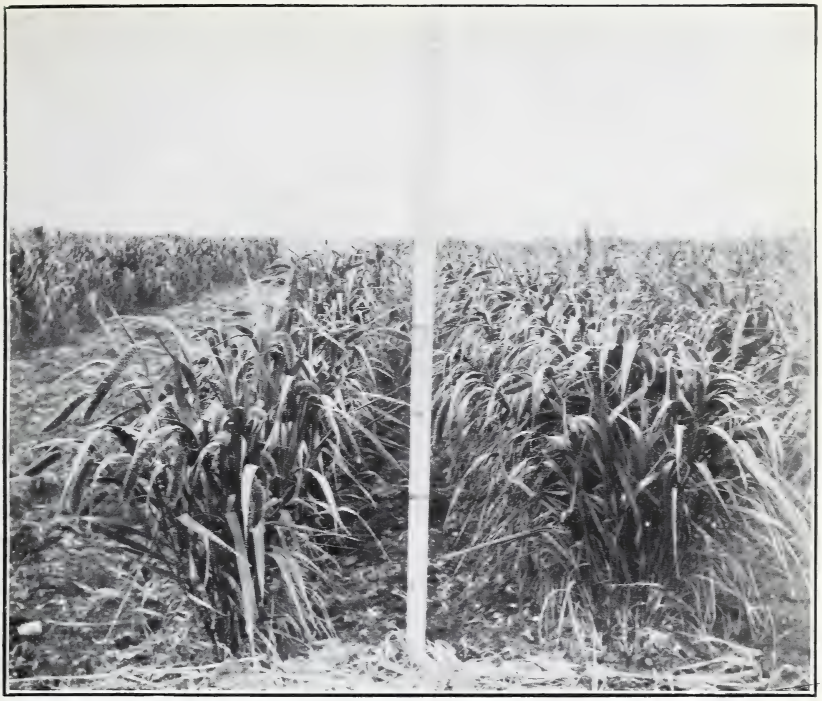

FIG. 1.—SELECTION ROWS.

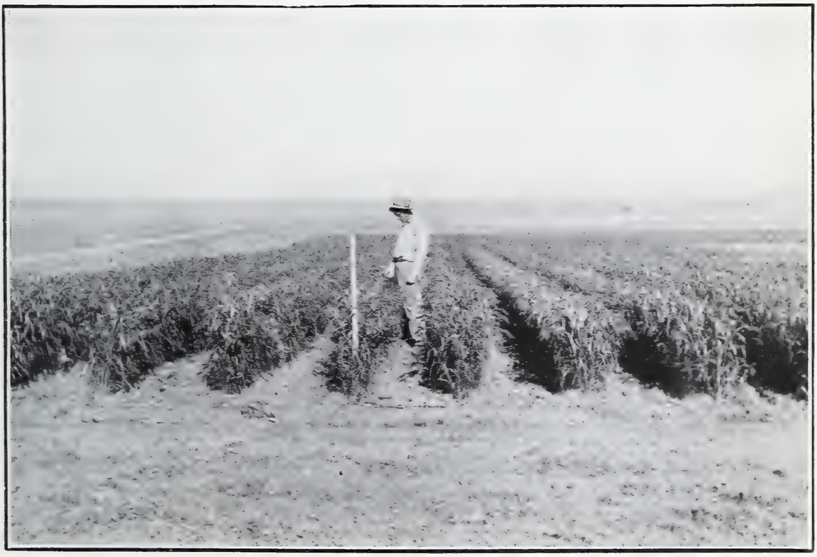

FIG. 2.—PROGENY ROWS.

KURSK MILLET AT THE BELLEFOURCHE EXPERIMENT FARM, SOUTH DAKOTA.

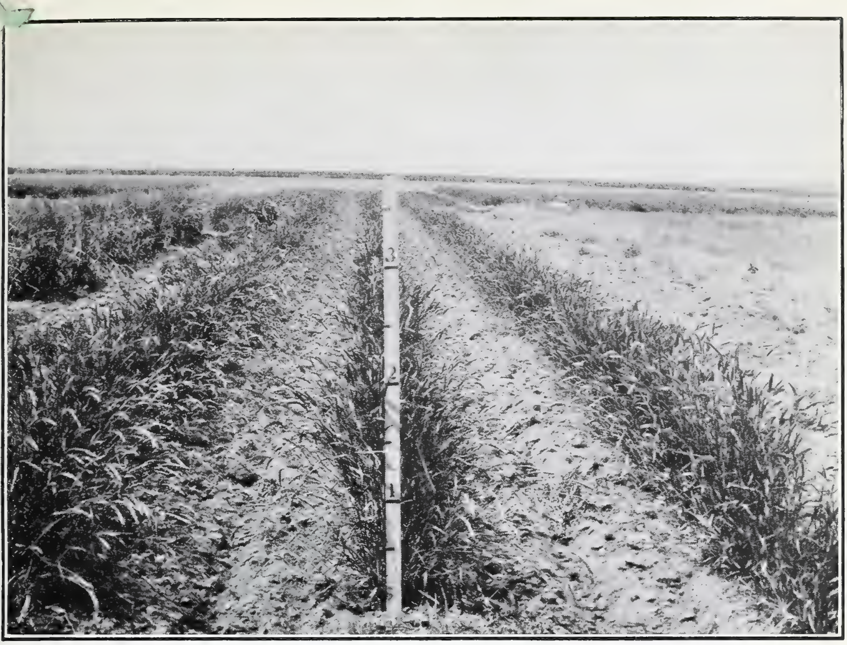

FIG. 1.—ROWS OF AGROPYRON CRISTATUM.

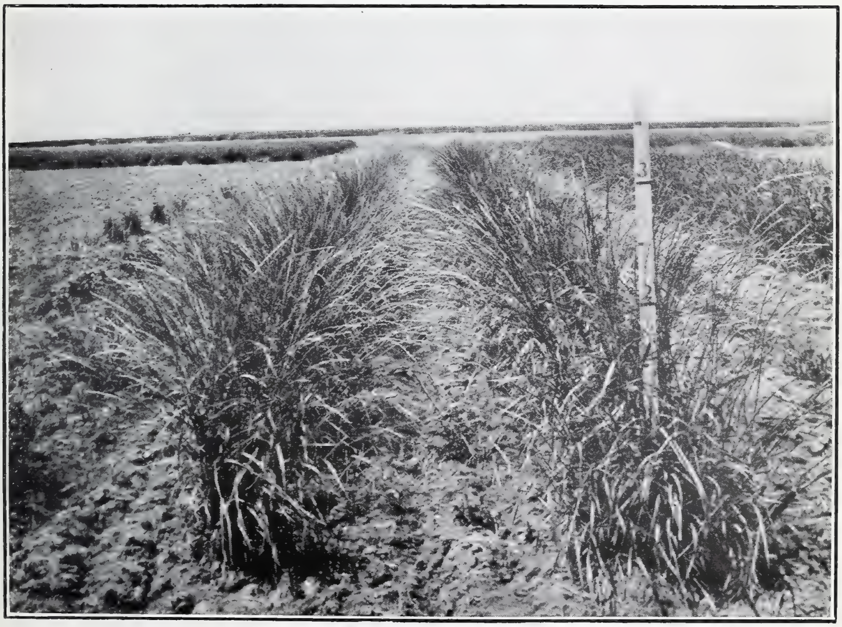

FIG. 2.—ROWS OF AGROPYRON TENERUM.

AGROPYRON IN THE GRASS NURSERY AT THE BELLEFOURCHE EXPERIMENT FARM, SOUTH DAKOTA.

INDEX.

Page.
Agropyron cristatum, breeding experiments ... 32, 36
smithii. *See* Grass, wheat, western.
tenerum. *See* Grass, wheat, slender.
Akron Dry-Land Station. *See* Experiments.
Alfalfa, breeding for drought resistance ... 7, 9–10, 12–20, 33–34, 36
comparative yields ... 17, 18
price per ton, comparison ... 30
varieties, Grimm ... 14, 18, 20
Minnesota No. 3 ... 14
South Dakota Nos. 65, 66, 67, 150, 162, 164 ... 13–15
Turkestan ... 14, 15, 18
Altitude, of certain stations ... 12
Analyses, chemical, of certain forage plants ... 30
Ashcroft, S. Dak., climatic records ... 11, 18
Awnless brome-grass. *See* Grass, brome.
Barley, tests of drought-resistant varieties ... 8
Bellefourche Experiment Farm. *See* Experiments.
Bouteloua oligostachya. *See* Grama, blue.
Brand, C. J., on alfalfa growing ... 14, 19
Breeding, plant, methods used ... 7, 15–16, 23, 24, 25, 29–31, 33–34
objects sought ... 7–9, 31–34
See also names of crops tested; as, Alfalfa, Grass, Legumes, Millet, and Sorgo.
Briggs, L. J., and McLane, J. W., on soil moisture ... 11
Bromus inermis. *See* Grass, brome, smooth.
Brookings, S. Dak., test of alfalfa ... 13, 14
Bulbilis dactyloides. *See* Grass, buffalo.
Canada peas. *See* Peas, Canada.
Chaetochloa italica. *See* Millet.
Climate, conditions to be met ... 7–8, 12, 24, 33
See also Rainfall and Temperature.
Clover, tests for drought resistance ... 9–10
Cole, John, work in plant breeding ... 15
Conclusion of bulletin ... 34
Cooperation with Office of Dry-Land Agriculture ... 10, 12, 15, 21
Forage-Crop Investigations ... 7, 10, 24–25, 29, 31, 32, 33
Western Agricultural Extension ... 10
Reclamation Service ... 10
South Dakota Agricultural Experiment Station ... 10, 15, 24, 29
Corn, comparison of drought-resistant power ... 8
Crops, comparative tests, by Office of Grain Investigations ... 8
leguminous, necessity in dry-land farming ... 32
methods to increase production ... 33
Deadwood, S. Dak., prices of alfalfa and western wheat-grass hay ... 30
Department of Agriculture, importation of drought-resistant plants ... 8, 13, 14, 32
Earliness. *See* Maturity.

Page.
Excelsior, Minn., cultivation of alfalfa 14
Experiments, at Akron Dry-Land Station 10, 12, 19, 23, 27–29
        Bellefourche Experiment Farm 10–33, 36
        Highmore substation 9–10, 12–15, 18–22, 24, 29, 31, 33, 36
    objects sought 7–9
Flowers of alfalfa 15, 16
    sorgo 21
Foliage, factor in forage yield 14, 15, 22, 29, 32
Forage, yield and quality 9, 12–15, 17–18, 22–24, 28–29, 33–34
Grain, yield and quality 9, 12–13, 14, 15, 17–19, 28–29, 33–34
Grama, blue, chemical analysis 30
Grass, brome, chemical analysis 30
        experiments, breeding 9–10, 29, 33
        variety, South Dakota No. 26, character and test 29
    buffalo, chemical analysis 30
    native, chief dependence of early agriculture 8
    wheat, slender, chemical analysis 30
            experiments, breeding 31–32, 33, 36
        western, chemical analysis 30
            tests for drought resistance 9–10, 30–31, 33
Great Plains, definition of area covered 7
Green-manure crops. *See* Legumes.
Gumbo, soil resultant from Pierre shale 11, 30
Hansen, N. E., importations of seeds 14, 25
Hardiness, factor in plant breeding 9, 11–14, 18–19, 33
Hay. *See* Forage.
Highmore substation. *See* Experiments.
History of investigations 9–10
Introduction to bulletin 7
Irrigation, outline of project at Bellefourche 10–11
    production of alfalfa seed 9
Kafirs, power of resisting drought 8
Kearney, T. H., drought-resistant plant-breeding work 10
Kepner, F. E. *See* Knight, H. G.
Knight, H. G., and Kepner, F. E., on analyses of forage plants 30
Lathyrus sativus. *S*ee Peas, grass.
Leaves of alfalfa. *See* Foliage.
Legumes, cultivation for green manure 32
McLane, J. W. *See* Briggs, L. J.
Maturity, factor of earliness 9, 19, 21, 22, 24, 27, 31, 33
Merke, Turkestan, source of alfalfa 14
Millet, tests for drought resistance 7, 9–10, 24–29
    varieties, common 24–28
        foxtail 10, 24–29, 36
        German 24–27
        Hungarian 24–27
        Kursk 24–29, 36
        Siberian 24–28
        S. P. I. No. 20694 25
        S. P. I. No. 22420 24
Milo, power of resisting drought 8, 9
Minnesota, origin of alfalfa variety, Minnesota No. 3 14

Page.
Moisture, conservation in soil ... 8, 9, 11, 12, 33
Oats, drought-resistant varieties ... 8
Office of Dry-Land Agriculture. *See* Cooperation.
  Forage-Crop Investigations. *See* Cooperation.
  Grain Investigations. *See* Crops, comparative tests.
  Western Agricultural Extension. *See* Cooperation.
Peas, Canada, breeding experiments ... 32
  grass, breeding experiments ... 32
Phleum pratense. *See* Timothy.
Pierre shale formation. *See* Gumbo.
Plant breeding. *See* Breeding.
Planting, alfalfa, method used for maximum seed yield ... 19–20, 33, 36
Plants, characters required for semiarid region ... 7–9, 16, 22
Plates, description ... 36
Pollination of alfalfa ... 16
  sorgo ... 21
Precipitation. *See* Rainfall.
Prices of alfalfa and western wheat-grass hay ... 30
Rainfall, factor in plant breeding ... 9, 11–13, 28
Range, character of industry ... 8
Reclamation Service. *See* Cooperation.
Screens, proposed use to insure self-pollination ... 16
Seed, distribution of superior strains ... 19, 21, 23, 24, 34
  production. *See* Grain.
Selection, factors governing method in plant breeding ... 8–9, 23
Shepard, J. H., on analyses of forage plants ... 30
Shrinkage of soil in drying, effect on plants ... 11
Siberia, origin of Agropyron cristatum ... 32
Slender wheat-grass. *See* Grass, wheat.
Soils, factor in plant-breeding work ... 11, 12, 21, 30, 32
Sorghum, tests for drought resistance ... 9–10
Sorgo, breeding for drought resistance ... 7–8, 9, 10, 20–23, 33, 36
  varieties, Montana, origin ... 21
    Orange, proposed culture at Akron, Colo ... 23
    Red Amber, proposed culture at Akron, Colo ... 23
    South Dakota No. 341, character and breeding ... 21–22, 36
South Dakota Agricultural Experiment Station. *See* Cooperation.
Sowing, broadcast, alfalfa, comparative yield ... 19–20
  Kursk millet, results ... 29
Stations, dry-land, as located, representative of Great Plains conditions ... 7, 10–12, 33
  experiment. *See* Cooperation and Experiments.
Stock, live, chief industry of Great Plains area ... 8
Summary of bulletin ... 33–34
Temperature, factor of plant breeding ... 11, 18–19
Timothy, chemical analysis ... 30
Turkestan, source of plant introductions ... 13, 14, 25
Uniformity, factor in plant breeding ... 16, 21, 22–23, 27, 33, 36
Varieties, tests of drought-resistant plants ... 7–9, 10
  See also Alfalfa, Millet, Sorgo, etc.
Vetches, breeding experiments ... 32
Western wheat-grass. *See* Grass, wheat.
Westgate, M., J. on alfalfa growing ... 14, 19

Page.
Wheat, tests of drought-resistant varieties.. 8
    grass. *See* Grass, wheat.
Wheeler, W. A., plant breeding for drought resistance.............. 9, 10, 13, 14, 15, 31
Winterkilling. *See* Hardiness.
Yield of alfalfa.. 14, 16–20
    millet.. 26–27, 28
    sorgo.. 21–22

○